6. POTENTIAL FOR HUMAN EXPOSURE

6.1 OVERVIEW

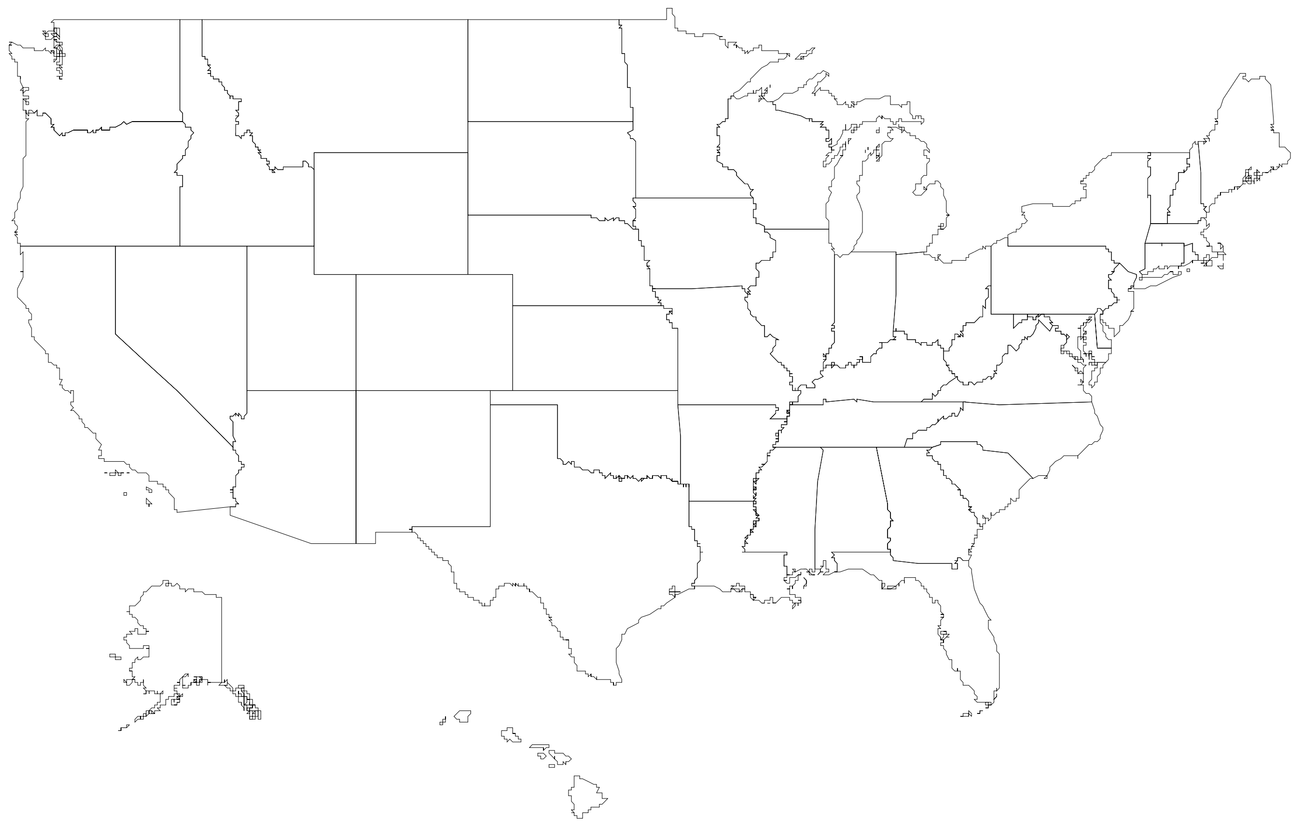
Synthetic vitreous fibers were not identified in any of the 1,613 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2002). However, the number of sites evaluated for synthetic vitreous fibers is not known. The frequency of these sites can be seen in Figure 6-1.

Like other inorganic substances, synthetic vitreous fibers do not undergo typical transformations in the environment, such as photolysis and biodegradation, that are important for organic compounds. Under acidic or alkaline conditions, synthetic vitreous fibers may undergo dissolution, whereby the silicate network may be attacked and slowly degraded. Because of their amorphous structure, synthetic vitreous fibers undergo dissolution at a rate about 2–4 times that of crystalline fibers such as asbestos. This degradation mechanism is more relevant in biological systems than it is in the environment (see Section 3.4 for more details). The transport and partitioning of synthetic vitreous fibers are largely governed by their size. Large fibers are removed from air and water by gravitational settling at a rate dependent upon their size, but small fibers may remain suspended for long periods of time.

The general population can be exposed to low levels of synthetic vitreous fibers when insulating material or other synthetic vitreous fiber-containing material such as ceiling boards are physically disturbed and fibers become suspended in the air. Home, building, and appliance insulation are often composed of glass wool, rock wool, or slag wool, and low levels of synthetic vitreous fibers have been detected in indoor air. These levels are usually on the order of about 1×10^{-4} fiber/cc, although higher levels are often observed during the installation of insulation in attics or ceilings; however, these levels quickly return to pre-installation levels, usually in 1 or 2 days. Low levels of synthetic vitreous fibers have also been detected in outdoor air, and available data suggest that there are little differences in the concentration of these fibers near source dominated areas (e.g., near production plants) when compared to other locations. Typical levels of synthetic vitreous fibers in outdoor ambient air can vary, but are also on the order of about 1×10^{-4} fiber/cc.

The overwhelming majority of human exposure to synthetic vitreous fibers occurs as occupational exposure through inhalation and dermal contact. Occupational exposure is estimated to be several orders

Figure 6-1. Frequency of NPL Sites with Synthetic Vitreous Fiber Contamination



Derived from HazDat 2002

of magnitude greater than environmental exposure. Employees at manufacturing facilities where synthetic vitreous fiber products are produced, as well as workers who regularly install or come into contact with insulating material are most at risk for elevated levels of exposure. Workers involved in demolition work, as well as in building maintenance and repair, are potentially exposed to higher levels of synthetic vitreous fibers once these materials are disturbed or demolished. Workers involved in the removal of refractory ceramic fiber insulation in high temperature furnaces may also be exposed to quartz, cristobalite, and tridymite, which form as refractory ceramic fibers devitrify at elevated temperatures (Maxim et al. 1999b).

In the literature discussing data on airborne synthetic vitreous fibers, total dust or total fiber levels are occasionally reported. These levels include all types of fibers, not just the synthetic vitreous fibers, and quite often synthetic vitreous fibers only constitute a small percentage of the total concentration of fibers in the sample. The precise definition of what constitutes an actual fiber, and how these fibers should be counted under microscopic examination is not standardized, and different studies have used different counting methods (see Chapter 7). A fiber is usually defined as having length of at least 5 µm, and a length to diameter ratio (aspect ratio) of either 5:1 or 3:1 (TIMA 1993). Frequently, only the levels of respirable fibers are reported. Respirable fibers are those fibers that can be inhaled into the lower lung, and usually only fibers with diameters of <3 µm are considered respirable in humans (although some authors have used larger values in older publications). It is also generally accepted that fibers longer than 200–250 µm are too large to be deposited in the lung, and are therefore not respirable (TIMA 1993). Recently, the American Conference of Governmental Industrial Hygienists (ACGIH) has defined respirable fibers as possessing a diameter <3 µm, length $5 µm, and an aspect ratio of $3:1 (ACGIH 2001). The term respirable fiber in this chapter refers to fibers possessing diameters of <3 µm, unless otherwise noted. Section 3.4 (Toxicokinetics) discusses the deposition and clearance of fibers in the lung in more detail.

Phase contrast microscopy (PCM) is most frequently used to measure fiber levels, but this method cannot detect fibers with diameters smaller than 0.25 µm. PCM uses visible light photons for analysis, and because the resolution of a microscope is a function of the wavelength of photons used for analysis and the numerical aperture of the microscope, the theoretical limit of 0.25 µm for light microscopy cannot be improved upon. Transmission electron microscopy (TEM) or scanning electron microscopy (SEM) are often employed to improve sensitivity since these techniques can measure fibers with smaller diameters than PCM because electrons with much shorter wavelengths than visible photons are used in these experiments (see Chapter 7 for details). It is often difficult to directly compare results of early studies to more recent ones due to the methods in which fibers were sampled and analyzed. Many early monitoring studies employed a set of fiber counting rules specifying a fiber as a particle with length >5 μm and aspect ratio of $3:1 (counting rules A). More recent studies frequently use a counting rule in which fibers are counted if their lengths are >5 μm, their diameters are <3 μm, and their aspect ratio is $5:1 (counting rules B). While the differences in actual fiber counts are usually small, calculating fibers using counting rules A generally yield higher counts as compared to the counting rules B (Breysse et al. 1999; Miller et al. 1995). See Chapter 7 for more details regarding the analysis, sampling, and counting of fibers.

The Toxics Release Inventory (TRI) has not listed synthetic vitreous fibers for inclusion in its database (TRI99 2002).

6.2 RELEASES TO THE ENVIRONMENT

Low levels of synthetic vitreous fibers may be released to the environment during their production or use. Demolishing buildings or houses that contain synthetic vitreous fibers in insulating products, ceiling boards etc., may also release low levels of synthetic vitreous fibers locally. The majority of releases most likely arises from the disposal of material containing synthetic vitreous fiber in landfills.

6.2.1 Air

Very limited data are available regarding the emission of synthetic vitreous fibers to ambient air. The concentration of synthetic vitreous fibers in air emissions from fibrous glass, rock wool, and slag wool plants in Germany were on the order of 0.01 fiber/cc, and the total fibrous dust emissions from these plants were estimated as 1.8 tons/year (WHO 1988). Concentrations of respirable fibers as high as 2.7 fibers/cc were measured by PCM in stack gasses at several older glass, rock, and slag wool plants in the United States (Environment Canada 1993). Concentrations of total fibers in stack gasses measured in 1991 using TEM at four refractory ceramic fiber production plants and three refractory ceramic fiber processing facilities ranged up to 14.1 fibers/cc (Environment Canada 1993).

Synthetic vitreous fibers were not identified in any of the current or former NPL hazardous waste sites (HazDat 2002). Synthetic vitreous fibers were not included in the TRI (TRI99 2002).

6.2.2 Water

Few data exist regarding the frequency or levels of synthetic vitreous fibers released to water. Glass fibers were identified in samples of sewage sludge from five cities in the United States; however, the specific form and exact quantity of the glass fibers were not reported (Bishop et al. 1985).

Synthetic vitreous fibers were not identified in any of the current or former NPL hazardous waste sites (HazDat 2002). Synthetic vitreous fibers were not included in the TRI (TRI99 2002).

6.2.3 Soil

No data exist regarding the frequency or levels of synthetic vitreous fibers released to soil. Most of these releases are expected to be in the form of discarded construction material (e.g., insulation, ceiling boards, etc.) that have been disposed of at landfills.

Synthetic vitreous fibers were not identified in any of the current or former NPL hazardous waste sites (HazDat 2002). Synthetic vitreous fibers were not included in the TRI (TRI99 2002).

6.3 ENVIRONMENTAL FATE

6.3.1 Transport and Partitioning

The transport, distribution, and degradation of synthetic vitreous fibers in the environment have not been studied (WHO 1988). However, synthetic vitreous fibers are nonvolatile and generally insoluble, so their natural tendency is to settle out of air and water, and deposit in soil or sediment.

6.3.2 Transformation and Degradation

6.3.2.1 Air

Synthetic vitreous fibers are not known to undergo any significant transformation or degradation in air (WHO 1988).

6.3.2.2 Water

Synthetic vitreous fibers are not known to undergo any significant transformation or degradation in water (WHO 1988). The silicate network of all synthetic vitreous fibers can be attacked by acids or alkaline solutions, but this does not occur to any significant extent under environmentally relevant conditions. Using *in vitro* tests at 37EC with simulated extracellular fluid (pH 7.4), the dissolution rates of glass, rock, and slag wools with diameters of 1 μm were reported as 0.4, 1.2, and 2.0 years, respectively (Environment Canada 1993). Lifetimes for refractory ceramic fibers were about 5 years. Because of their larger surface area, fine fibers will undergo dissolution more readily than course fibers (see Section 3.4 for more details regarding dissolution in biological media).

6.3.2.3 Sediment and Soil

Synthetic vitreous fibers are not known to undergo any significant transformation or degradation in soil or sediment (WHO 1988).

6.3.2.4 Other Media

6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

6.4.1 Air

Available monitoring data suggest that the concentration of synthetic vitreous fibers in the atmosphere is very low. The level of fibrous glass in ventilation systems and in the ambient air from various locations of California were studied from 1968–1971, in order to investigate the erosion of fibers from air transmission systems (Balzer et al. 1971; NIOSH 1976). The concentration of fibrous glass in 36 ambient air samples collected from Berkeley, San Jose, Sacramento, the Sierra Mountains, and Los Angeles ranged from not detected to 9.0×10^{-3} fiber/cc, with an arithmetic mean of 2.57×10^{-3} fiber/cc, as determined by PCM and TEM (NIOSH 1976). The fiber diameters ranged from 0.10–17.7 μm, with an arithmetic mean of 4.3 μm. The concentration of fibrous glass in 37 ventilation system samples ranged from not detected to 2.0×10^{-3} fiber/cc (8.7×10^{-4} fiber/cc, arithmetic mean), and the fiber diameters were 0.10–17.7 μm (3.7 μm, arithmetic mean). The mean airborne concentration of fibers were monitored at one rural location and three cities in Germany in 1981–1982 (Hohr 1985). Samples were analyzed with TEM in conjunction with energy-dispersive x-ray analysis (EDXA), and electron diffraction analysis.

The fibers identified as synthetic vitreous fibers constituted >1–5% of the inorganic fibers, with a concentration range of $4.0x10^{-5}$–$1.7x10^{-3}$ fiber/cc (Hohr 1985). The results of these, and several other past monitoring studies have been compiled and summarized in IARC (1988) and WHO (1988).

The concentration of respirable glass fibers near a large fiberglass wool manufacturing facility in Newark, Ohio ranged from below the detection limit of $1.0x10^{-5}$ fiber/cc to $1.4x10^{-4}$ fiber/cc, during four sampling periods in 1988–1989 as determined by PCM (Switala et al. 1994). These levels were similar to the measured levels in ambient air from a rural site located 10 miles away from the plant in Granville, Ohio. The range of concentrations at the rural location was from below the detection limit of $1.0x10^{-5}$ fiber/cc to $1.5x10^{-4}$ fiber/cc, during the same sampling period. Furthermore it was shown that only 16% of the 460 samples obtained at the Newark (plant) location had concentrations of glass fibers above the detection limit and only 4% of the 485 samples obtained from the Granville (rural) location had concentrations above the detection limit. Glass fibers accounted for <1% of the total respirable fibers measured at these sites. The total respirable fiber concentrations (this includes all fibers, not just synthetic vitreous fibers) at the Newark location ranged from below the detection limits to 0.02318 fiber/cc, while the levels of total respirable fibers at the Granville site ranged from below the detection limits to 0.04290 fiber/cc. The majority of non-glass fibers were reported to be pollen and trichome, seed hairs, and insect parts (Switala et al. 1994). Low levels of synthetic vitreous fibers in ambient air have also been measured in various locations in France (Gaudichet et al. 1989). The maximum concentration of respirable synthetic vitreous fibers in outdoor air at 18 locations in Paris was $1.5x10^{-5}$ fiber/cc, with a mean value of $2.0x10^{-6}$ fiber/cc as determined by PCM (Gaudichet et al. 1989).

In general, indoor air concentrations of synthetic vitreous fibers are very low under non-occupational settings, unless there is a disturbance in the fiberglass insulation system or ceiling boards of the home or building. A comprehensive study using PCM was carried out in Denmark in order to study the concentration of synthetic vitreous fibers in the indoor air of public buildings (Schneider et al. 1990). The concentration of respirable airborne synthetic vitreous fibers ranged from not detected to $1.66x10^{-3}$ fiber/cc in air samples collected from 105 rooms using 10 different types of ceiling boards. The mean respirable levels were in the range of $2.60x10^{-5}$–$2.13x10^{-4}$ fiber/cc. The levels of nonsynthetic vitreous fibers were at least an order of magnitude greater than the levels of synthetic vitreous fibers. It was also reported that no respirable airborne levels of synthetic vitreous fibers were observed in 65 of the rooms, but that low levels of respirable synthetic vitreous fibers were found on other objects such as tables or cupboards (Schneider et al. 1990). The results of this study pertaining to the levels of airborne synthetic vitreous fibers are summarized in Table 6-1.

A recent study employing both PCM and SEM analyzed 51 residential and commercial buildings throughout the United States, and found respirable synthetic vitreous fibers were present in only 2 of the 50 samples analyzed by SEM (Carter et al. 1999). It was demonstrated that the majority of airborne fibers were organic, and that inorganic fibers, including synthetic vitreous fibers, composed <10% of the detectable respirable amount. Gaudichet et al. (1989) measured the levels of synthetic vitreous fibers at 79 indoor locations in France where synthetic vitreous fiber materials were used in a variety of applications, and found the levels of respirable synthetic vitreous fibers to be low. A range of respirable synthetic vitreous fibers were reported as not detected to 6.23×10^{-3} fiber/cc with a median value of 3.0×10^{-6} fiber/cc (Gaudichet et al. 1989). The levels of respirable fibers (diameter <3 μm and lengths >5 but <100 μm) were measured in 12 houses during the installation of rock wool or glass wool insulation material by PCM and TEM (Jaffrey 1990). Almost no differences were noticed in the pre-installation airborne levels, which were on the order of 1.0×10^{-4} fiber/cc, and the post insulation samples, which were taken 2 days after installation was complete. Comparable results were obtained by Miller et al. (1995) when analyzing the fiber concentrations in living spaces of 14 homes prior to installation of insulation and the evening following installation. Total fiber levels ranged from 0.0020 to 0.011 fiber/cc before installation, and from 0.0030 to 0.015 fiber/cc 1 day post-installation using PCM and counting rules A (see Chapter 7). Fiber concentrations calculated using counting rules B were slightly lower, but there was no statistically significant differences when comparing levels calculated by either the A or B counting rules. Similar results were obtained when using SEM methods and the two counting rules to measure only synthetic vitreous fibers levels, although the level of fibers classified as synthetic vitreous fibers were about an order of magnitude lower than the total fiber levels. The maximum pre-installation level of synthetic vitreous fibers was 0.001 fiber/cc, and the post-installation levels ranged from below the detection limit of 0.001 fiber/cc to 0.007 fiber/cc.

6.4.2 Water

No data exist regarding the ambient levels of synthetic vitreous fibers in water.

Table 6-1. Airborne Concentrations of Synthetic Vitreous Fibers in Buildings in Denmark[a]

Type of ceiling board[b]	Number of rooms	Water soluble binder	Respirable fiber level fibers/cc; range (mean)	Non-respirable fiber level fibers/cc; range (mean)
Karlit mineral	11	Yes	0–1.66x10^{-3} (2.13x10^{-4})	0–3.3x10^{-4} (5.7x10^{-5})
Hotaco mineral	14	Yes	0–4.3x10^{-4} (5.6x10^{-5})	0–1.9x10^{-4} (2.1x10^{-5})
Ny Hotaco mineral	2	Yes	6–13x10^{-5} (9.5x10^{-5})	Not detected
Other with water soluble binder	12	Yes	0–3.6x10^{-4} (5.9x10^{-5})	0–7.0x10^{-5} (1.4x10^{-5})
Soft mineral wool sealed on three sides	13	No	0–3.4x10^{-4} (2.6x10^{-5})	0–1.0x10^{-4} (8.0x10^{-6})
Hard mineral wool sealed on three sides	9	No	0–1.3x10^{-4} (3.1x10^{-5})	0–7.0x10^{-5} (1.0x10^{-5})
Unsealed mineral wool	12	No	0–1.03x10^{-3} (1.8x10^{-4})	0–4.0x10^{-4} (6.7x10^{-5})
Sealed mineral wool on all six surfaces	9	No	0–6.1x10^{-4} (9.4x10^{-5})	0–2.4x10^{-4} (4.6x10^{-5})
Batts on top of perforated panels	11	No	0–1.0x10^{-4} (1.7x10^{-5})	0–6.0x10^{-5} (9.0x10^{-6})
No synthetic vitreous fiber (control group)	12	Not applicable	0–6.2x10^{-4} (6.2x10^{-5})	0–1.3x10^{-4} (1.8x10^{-5})

[a]Schneider et al. 1990
[b]Contains Danish product names

6.4.3 Sediment and Soil

No data exist regarding the ambient levels of synthetic vitreous fibers in soil or sediment.

6.4.4 Other Environmental Media

No data exist regarding the levels of synthetic vitreous fibers in foods, plants, or animals.

6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The exposure of the general population (non-occupational exposure) to synthetic vitreous fibers in both indoor and outdoor air is low. Persons that install their own home insulation may briefly be exposed to higher than normal levels during the installation; however, these exposures can be significantly reduced with the use of protective equipment such as ventilators and gloves. Furthermore, it has been shown that the airborne levels of synthetic vitreous fibers attenuate rapidly following installation (Jaffrey 1990; Miller et al. 1995). No exposures from food, drinking water, or other environmental media are expected.

The airborne levels of synthetic vitreous fibers have been shown to be higher under occupational settings as compared to ambient air levels, and thus, occupational exposure is far greater than the exposure for the general population. Esmen and Erdal (1990) concluded that occupational exposure is several orders of magnitude greater than environmental exposure. The Occupational Safety and Health Administration (OSHA) estimates that there are over 250,000 workers in the United States who are exposed to synthetic vitreous fibers in manufacturing and downstream use (OSHA 2002). This number is expected to increase as use of products containing synthetic vitreous fibers increases.

Workers involved in the installation of fiberglass insulating material are exposed to synthetic vitreous fibers through both dermal and inhalation routes. Airborne fiber levels were studied by PCM during the installation of fibrous glass insulating materials in northern California (NIOSH 1976). The concentration of fibrous glass in 40 air samples obtained during the installation of this material ranged from 5.0×10^{-4} to 2.41 fibers/cc (0.406 fiber/cc, arithmetic mean) with diameters in the range of 0.30–25.0 μm (6.5 μm, arithmetic mean). These airborne levels were 2–3 orders of magnitude greater than levels typically found in ambient air (Balzer 1971; NIOSH 1976; Switala et al. 1994). Differences were noted in the concentration of glass fibers in personal air samples when comparing the installation of batt-type material with blown-in insulation. The arithmetic mean concentration of total glass fibers during the installation of batt-type insulation was 0.13 fiber/cc and the arithmetic mean respirable glass fiber concentration was 0.042 fiber/cc as determined by PCM (Jacob et al. 1992). The personal air concentrations were higher for applications involving blown-in insulation wool as compared to batt-type material. The arithmetic mean concentrations of total glass wool fibers were 0.68 fiber/cc (cubed blown wool) and 1.7 fibers/cc (milled blown wool) during the installation process. The corresponding arithmetic mean concentrations of respirable glass wool fibers were 0.30 fiber/cc for the milled blown wool and 0.82 fiber/cc for the cubed blown wool (Jacob et al. 1992). The levels of airborne respirable glass fibers were shown to decrease significantly after installation, however, with levels on the order of 1×10^{-4} fiber/cc 1 day after installation (Jacob et al. 1992). The respirable airborne concentrations of refractory ceramic fibers, rock wool, and glass wool fibers were measured by PCM and TEM at five construction sites using products containing these materials (Perrault et al. 1992). The greatest airborne level were observed during the removal of refractory ceramic fiber insulating material from the inside walls of industrial furnaces, with geometric mean concentrations ranging from 0.39 to 3.51 fibers/cc. The geometric mean concentration of respirable fibers during the installation of blown in rock wool in the attic of a residential apartment building was 0.32 fiber/cc, while the geometric mean concentration was 0.15 fiber/cc for sprayed-on rock wool insulation at an industrial construction site. The lowest airborne level were observed during the installation of fiberglass panels around ventilation ducts at an industrial construction site, with a geometric mean concentration of 0.010 fiber/cc (Perrault et al. 1992). Using TEM and PCM, the mean concentration of respirable airborne fibers were measured in the ranged from 0.080 to 1.76 fibers/cc during the installation of either glass wool or rock wool insulating material in 12 houses in England (Jaffrey 1990). The lowest airborne concentrations were observed during the installation of rock wool blanket material, and the highest level occurred during the installation of a fine glass wool blanket material, in which approximately 80% of the fibers had diameters <1 µm.

In a study of four facilities producing fibrous glass insulation and one producing fibrous glass textile products, the range of concentrations for total respirable fibers having lengths >5 µm were reported as not detected to 1.97 fibers/cc, with mean levels in the range of 0.020–0.97 fiber/cc (Johnson et al. 1969). No data were provided regarding what percentage of total fiber counts were glass fibers as opposed to other fibers, and respirable fibers in this study were defined as fibers having a diameter <5 µm, rather than the currently accepted value of <3 µm. The airborne level of fibers in various parts of 16 manufacturing facilities producing glass wool, continuous glass filament, rock and slag wool, and refractory ceramic fibers were measured by Esmen et al. (1979a, 1979b), and the details of this study have been summarized in other publications (IARC 1988; WHO 1988). Table 6-2 shows the levels of total suspended particulate matter in various regions of these 16 plants, and Table 6-3 shows the corresponding concentrations of total airborne fibers measured by PCM. The greatest airborne fiber levels of were observed at a plant producing refractory ceramic and special purpose fibers (plant 15), where the nominal fiber diameter of the product ranged from 0.050 to 1.6 μm. Additional studies employing transmission electron microscopy to detect small diameter fibers showed airborne fiber levels as high as 6.49 fibers/cc for this location. More recent monitoring data on workplace airborne levels confirm that higher concentrations are observed under occupational settings as compared to the levels observed under non-occupational conditions. In a study of airborne fiber levels during 11 different manufacturing operations involving Owens-Corning Fiberglass insulation products, the mean concentration of airborne total glass fibers ranged from 0.0020 to 0.14 fiber/cc and the mean concentration of respirable glass fibers ranged from 0.0010 to 0.071 fiber/cc as determined by PCM (Jacob et al. 1993). The airborne fiber levels were also studied during the removal of pipe installation and ceiling boards. For these removal processes, the mean airborne concentration of total glass fibers was 0.10 fiber/cc and the mean airborne concentration of respirable glass fibers was 0.042 fiber/cc (Jacob et al. 1993). While these levels are greater than levels found in ambient air, they are far lower than a 1992 proposed OSHA exposure limit of 1 fiber/cc per 8 hour time-weighted-average (TWA) (OSHA 2002).

The concentration of respirable (defined in this study as having diameters #3 μm) refractory ceramic fibers in personal air samples in seven manufacturing plants located in France, the United Kingdom, and Germany ranged from about 0.2 to 1.0 fiber/cc as determined by PCM (Trethowan et al. 1995). The levels of respirable airborne refractory ceramic fibers were studied by PCM at five manufacturing plants located in the United States over a 6-year period to assess differences in exposure levels during different work shifts in the plants (Hall et al. 1997). The geometric mean TWA exposure for all shifts at these five plants ranged from 0.080 to 0.35 fiber/cc, and little differences were observed in the level of exposure and which shift the measurements were obtained. Based on a 2-year survey of occupational exposure to refractory ceramic fibers in the United Kingdom, some typical exposure levels categorized by process description or job type were compiled (Friar and Phillips 1989). The results of this survey are summarized in Table 6-4. While high levels of exposure were estimated for certain job descriptions, it was noted that >60% of the exposure levels fall within the 0–0.5 fiber/cc range (Friar and Phillips 1989).

Table 6-2. Concentrations (mg/m^3) of Total Suspended Airborne Particulate Matter in 16 Facilities in the United States[a]

Plant	Forming mean (SD)	Production mean (SD)	Manufacturing mean (SD)	Maintenance mean (SD)	Quality control mean (SD)	Shipping mean (SD)	Overall mean (SD)
1	0.47 (0.47)	1.04 (1.34)	0.96 (0.96)	0.71 (0.45)	0.21 (0.12)	0.39 (0.09)	0.89 (1.12)
2	1.65 (1.17)	2.53 (2.30)	2.28 (1.51)	2.05 (1.32)	1.53 (0.63)	1.34 (0.58)	1.94 (1.68)
3	No data	0.51 (0.30)	No data	0.83 (0.61)	No data	0.70 (0.42)	0.65 (0.46)
4	1.22 (0.51)	0.77 (0.49)	1.23 (0.95)	2.08 (4.40)	0.52 (0.14)	1.32 (0.96)	1.24 (2.26)
5	0.76 (0.25)	0.67 (1.52)	0.29 (0.95)	0.55 (0.32)	0.09 (No data)	0.62 (0.33)	0.60 (1.04)
6	1.30 (0.71)	1.77 (2.23)	0.51 (0.39)	2.00 (2.50)	0.49 (0.82)	0.45 (0.19)	1.17 (1.72)
7	2.18 (1.62)	2.05 (0.31)	4.31 (4.03)	6.72 (7.84)	No data	1.77 (1.02)	4.00 (4.27)
8	No data	8.48 (9.02)	1.17 (0.55)	4.64 (8.28)	No data	0.84 (0.67)	4.73 (8.69)
9	1.18 (0.48)	1.90 (1.52)	1.14 (0.53)	1.33 (0.57)	No data	1.08 (0.46)	1.33 (1.02)
10	2.45 (0.93)	0.75 (0.47)	0.73 (0.33)	1.25 (1.07)	0.32 (0.09)	0.69 (0.15)	1.07 (0.91)
11	2.18 (1.64)	1.08 (1.82)	0.87 (0.46)	1.26 (0.49)	1.25 (No data)	1.04 (0.41)	1.37 (1.09)
12	0.34 (0.35)	0.20 (0.30)	0.28 (0.26)	0.53 (0.26)	0.53 (0.66)	0.88 (0.08)	0.21 (0.16)
13	4.10 (No data)	1.34 (0.46)	1.19 (1.08)	1.80 (1.69)	No data	1.31 (0.59)	1.40 (1.08)
14	3.00 (1.37)	0.85 (0.59)	1.06 (0.47)	1.57 (1.41)	No data	0.91 (0.72)	1.42(1.21)
15	0.30 (0.21)	0.61 (0.51)	1.08 (0.80)	1.09 (0.75)	1.66 (0.73)	0.54 (0.18)	0.75 (0.67)
16	0.77 (0.46)	0.82 (0.69)	0.86 (0.52)	1.79 (1.50)	0.44 (No data)	0.76 (0.53)	1.07 (1.02)

[a]Esmen et al. 1979b; measurements obtained with phase contrast microscopy

SD = standard deviation

Table 6-3. Concentrations (fiber(s)/cc) of Total Airborne Fibers in 16 Facilities in the United States[a]

Plant	ND µm	Forming area mean (SD)	Production area mean (SD)	Manufacturing area mean (SD)	Maintenance area mean (SD)	Quality control area mean (SD)	Shipping area mean (SD)	Overall mean (SD)
1	1–12	0.002 (0.001)	0.38 (0.32)	0.03 (0.02)	0.02 (0.02)	0.07 (0.10)	0.01 (0.001)	0.01 (0.25)
2	6	0.07 (0.03)	0.17 (0.14)	0.12 (0.11)	0.08 (0.05)	0.19 (0.16)	0.07 (0.06)	0.11 (0.12)
3	3–6	No data	0.02 (0.02)	No data	0.07 (0.18)	No data	0.005 (0.01)	0.04 (0.1)
4	1–6	0.01 (0.004)	0.07 (0.12)	0.04 (0.05)	0.03 (0.02)	0.01 (0.01)	0.02 (0.01)	0.04 (0.08)
5	8	0.02 (0.01)	0.03 (0.02)	0.03 (0.02)	0.02 (0.01)	0.03 (No data)	0.03 (0.01)	0.02 (0.02)
6	5–15	0.05 (0.10)	0.01 (0.01)	0.008 (0.01)	0.01 (0.03)	0.01 (0.02)	0.005 (0.004)	0.01 (0.03)
7	5	0.15 (0.03)	0.24 (0.12)	0.43 (0.32)	0.44 (0.37)	No data	0.15 (0.17)	0.34 (0.35)
8	7–10	No data	0.03 (0.02)	0.04 (0.03)	0.01 (0.01)	No data	0.01 (0.01)	0.02 (0.02)
9	7–10	0.02 (0.02)	0.01 (0.01)	0.02 (0.07)	0.01 (0.006)	No data	0.004 (0.002)	0.02 (0.01)
10	6–16	0.001 (0.001)	0.003 (0.004)	0.004 (0.004)	0.002 (0.003)	0.003 (0.003)	0.002 (0.002)	0.002 (0.003)
11	7	0.09 (0.11)	0.05 (0.03)	0.04 (0.03)	0.04 (0.04)	0.08 (0.08)	0.03 (0.02)	0.05 (0.05)
12	6–115	0.01 (0.01)	0.020 (0.030)	0.01 (0.004)	0.01 (0.02)	0.01 (0.003)	0.007 (0.005)	0.01 (0.02)
13	7	0.58 (No data)	0.08 (0.06)	0.11 (0.17)	0.09 (0.08)	No data	0.03 (0.02)	0.10 (0.10)
14	6–13	0.01 (0.01)	0.04 (0.09)	0.05 (0.05)	0.05 (0.13)	No data	0.03 (0.03)	0.04 (0.03)
15	0.05–1.6	0.19 (0.22)	0.92 (1.02)	1.56 (3.79)	0.11 (0.10)	0.89 (0.33)	0.10 (0.09)	0.78 (2.1)
16	6–10	0.02 (0.01)	0.02 (0.02)	0.05 (0.03)	0.07 (0.23)	0.04 (No data)	0.02 (0.01)	0.04 (0.12)

[a]Esmen et al. 1979b

ND = nominal diameter; SD = standard deviation

Table 6-4. Typical Exposures in the Manufacture and Use of Refractory Ceramic Fibers[a]

Process description or job	Exposure level (fiber(s)/cc)
Manufacture	
Needle operator	0.5
Baling raw fiber	0.4
Fiber chopping	0.8
Product reeling	0.8
Bagging/chopping raw fiber	1.2
Mixing during product formation	0.4
Packing products	0.02
Use	
Wrapping refractory ceramic fiber blanket around pipe weld	0.8
Stripping and relining furnace panel	1.2
Kiln building	1.75
Handling blanket refractory ceramic fiber	1.0
Machining and ventilation control of refractory ceramic fiber fireboard	0.6
Insulation work using blanket	1.0
Handling operations; manual handling, but with little cutting or machining	0.1

[a]Friar and Phillips 1989

The results of a comprehensive 54-month workplace monitoring study for exposure to refractory ceramic fibers in the United States has been published (Mast et al. 2000; Maxim et al. 1994). Although large differences were noted in the TWA exposures to workers performing various job functions, it was reported that of the nearly 3,000 samples obtained at facilities that process or use refractory ceramic fibers, 77% of the TWA measurements were below the industry recommended exposure guideline of 0.5 fiber/cc (Mast et al. 2000). It was also reported that approximately 84% of the samples obtained at refractory ceramic fiber producing facilities were below the recommended exposure guideline. Workers involved in the removal and installation of insulation from furnaces, as well as the finishing (use of drill presses, sanding, and sawing) of refractory ceramic fibers had the highest TWA exposures, while workers involved in mixing/forming, fiber manufacturing, product assembly, and auxiliary job categories had the lowest TWA. The TWA exposures ranged from about 0.2 fiber/cc for auxiliary and assembly workers to about 1.2 fibers/cc for workers involved in the removal of refractory ceramic fiber containing insulating material (Maxim et al. 1994). A significant decrease in the TWA exposure to workers over the period of 1990–1998 was observed as engineering controls and respirator use has improved (Mast et al. 2000).

Exposure to refractory ceramic fibers may pose an additional health hazard for workers involved in the removal of ceramic fiber insulation from high temperature industrial furnaces, since refractory ceramic fibers may be partially converted to quartz, cristobalite, and tridymite at elevated temperatures (Maxim et al. 1999). Tests performed on three refractory ceramic fiber containing insulation blankets showed that between 3 and 21% of the bulk fibers had been converted to cristobalite at temperatures in the range of 500–2,550 EF, with the majority of devitrification occurring on the surface layers of the hot face (Gantner 1986). The percentage of cristobalite in corresponding air samples ranged from 4.0 to 14.7% (Gantner 1986). No quartz or tridymite was detected. An analysis of the monitoring data led to the conclusion that personal exposure to cristobalite while removing insulation from the furnaces reached or exceeded the threshold limit value of 0.05 mg/m^3 in about 75% of the samples (Gantner 1986). A study was conducted to determine the level of exposure to refractory ceramic fibers during the installation and removal of insulation in 13 furnaces situated in 6 refineries and 2 chemical plants located in the United States (Cheng et al. 1992). The majority of exposures to refractory ceramic fibers were found to be low, with 8-hour TWA exposure levels of #0.2 fiber/cc for most of the tasks involved. However, airborne levels as high as 17 fibers/cc were observed when removing refractory ceramic fiber containing blankets inside of furnaces or when welders cut through crude oil furnace tubes when cutting away damaged metal parts while repairing a furnace (Cheng et al. 1992). Furthermore, the study found that workers who replaced worn out refractory ceramic fiber modules from the furnaces had exposure to cristobalite in dust samples ranging from 0.03 to 0.2 mg/m^3, with a geometric mean of 0.06 mg/m^3, which is above the OSHA established permissible exposure limit (PEL) of 0.05 mg/m^3 (Cheng et al. 1992). A more recent study conducted from 1993 to 1998 found that respirable quartz was detectable in only 14 of the 158 samples taken during the removal of insulation from industrial furnaces, respirable cristobalite was only detectable in 3 samples, and respirable tridymite was only detected in 1 sample (Maxim et al. 1999). However, the short sampling time of many of these collections led to relatively poor limits of detection due to the low volume of air collected during the analysis, and longer sampling times would likely indicate a higher percentage of detectable crystalline silica exposure.

6.6 EXPOSURES OF CHILDREN

This section focuses on exposures from conception to maturity at 18 years in humans. Differences from adults in susceptibility to hazardous substances are discussed in 3.7 Children's Susceptibility. Children are not small adults. A child's exposure may differ from an adult's exposure in many ways. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface in proportion to their body volume. A child's diet often differs from that of adults. The developing human's source of nutrition changes with age: from placental nourishment to breast milk or formula to the diet of older children who eat more of certain types of foods than adults. A child's behavior and lifestyle also influence exposure. Children crawl on the floor, put things in their mouths, sometimes eat inappropriate things (such as dirt or paint chips), and spend more time outdoors. Children also are closer to the ground, and they do not use the judgment of adults to avoid hazards (NRC 1993).

Children may be exposed to low levels of synthetic vitreous fibers in the same ways that adults are exposed outside the workplace. This exposure primarily occurs from inhaling low levels of synthetic vitreous fibers from ambient and household air, or air from schools and other public buildings. Differences in breathing patterns, airflow velocity, and airway geometry between adults and children can result in age-related differences in deposition of inhaled particles in the respiratory tract (Phalen et al. 1985). Deposition of particles in various regions of the respiratory tract in children may be higher or lower than in adults depending on particle size, but for particles with diameters <1 μm, fractional deposition in the alveolar, tracheobronchial, and nasopharyngeal regions in 2-year-old children has been estimated to be about 1.5 times higher than in adults (Xu and Yu 1986). A study conducted by Schneider et al. (1996) attempted to evaluate the personal exposure of individuals residing in different parts of Europe to organic and inorganic fibers. It was determined that out of the four groups studied (suburban school children, rural retired persons, office workers, and taxi drivers), schoolchildren had the greatest exposure to total fiber counts. The mean concentration of total respirable fibers in the personal air samples of schoolchildren was 0.02 fiber/cc (Schneider et al. 1996). However, it was shown that the majority of respirable fibers were organic fibers and inorganic fibers other than synthetic vitreous fibers (particularly gypsum), and the level of exposure to fibers consistent with synthetic vitreous fibers was very low.

The airborne fiber concentration in kindergartens in Denmark was studied to determine if there was a correlation between respiratory problems and fiber concentrations in the schools (Rindel et al. 1987; Schneider 1986). The mean concentrations of respirable fibers in schools with ceiling boards containing synthetic vitreous fibers with water-soluble binders and resin binders were $1.1x10^{-4}$ and $9.7x10^{-5}$ fiber/cc, respectively. The mean concentration in kindergartens using ceiling boards that did not contain synthetic vitreous fibers was $4.1x10^{-5}$ fiber/cc. It was concluded that no correlation existed between respiratory symptoms or disease and synthetic vitreous fibers exposure (Rindel et al. 1987; Schneider 1986).

Since children tend to play on carpets and floors, and thus, they may also be exposed to synthetic vitreous fibers that have been deposited on theses surfaces, but the levels are expected to be very low (Schneider et al. 1990).

6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

The people most likely to have high exposure to synthetic vitreous fibers are workers who come into contact with products containing these fibers while on the job. This includes people involved in the manufacture of synthetic vitreous fiber-containing products, and also people who install, service, remove, or use these products. Workers engaged in the demolition of buildings with synthetic vitreous fiber-containing materials are also potentially exposed. Workers involved in the installation or servicing of furnaces that contain refractory ceramic fiber insulation may also be exposed to quartz, cristobalite, and tridymite. Workers may also carry home deposited synthetic vitreous fibers from their clothing or in their hair, resulting in exposure of family members; however, this is not likely to be of concern at the present.

Lung tissue samples were obtained from the autopsies of 145 former employees of 17 synthetic vitreous fiber plants located in the United States (McDonald et al. 1990). Levels of total fibers were approximately 60% greater in workers than in people who were not occupationally exposed, but the majority of detectable fibers were not synthetic vitreous fibers. While certain fibers were classified as synthetic vitreous fibers, no further identification as to exact type of synthetic vitreous fibers was possible. Furthermore, only four individuals that were occupationally exposed had synthetic vitreous fibers lung concentrations >0.2 fiber/µg lung tissue (one worker had a concentration of 1 fiber/µg), the rest had concentrations below 0.2 fiber/µg (McDonald et al. 1990). The geometric mean fiber length, fiber diameter, and aspect ratio were 7.5 µm, 1.0 µm, and 8.0, respectively, for those occupationally exposed, while the values for the referents were 6.6 µm, 1.2 µm, and 6.1, respectively.

Although data are scarce, current monitoring data do not support the assumption that persons residing near plants where synthetic vitreous fibers are produced will be exposed to higher levels of these fibers in the ambient air than persons who reside distal from such plants (Switala et al. 1994).

6.8 ADEQUACY OF THE DATABASE

Section 104(I)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of synthetic vitreous fibers is available. Where adequate information is not available, ATSDR, in conjunction with the National Toxicology Program (NTP), is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of synthetic vitreous fibers.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that if met would reduce the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

6.8.1 Identification of Data Needs

Physical and Chemical Properties. The physical and chemical properties of synthetic vitreous fibers are generally well characterized (see Chapter 4), and there does not appear to be a need for further research in this area. However, continuing characterization of new fibers, particularly the physical dimensions of the fibers and products, will be necessary as they are produced.

Production, Import/Export, Use, Release, and Disposal. Data regarding the import and export volumes of glass fibers, refractory ceramic goods, and mineral wool exist (USDOC 2002). While production volumes are available for synthetic vitreous fibers (GMIC 2002; Mast et al. 2000), more recent data would be useful. There is also a data need to have an estimate of the annual amount of synthetic vitreous fiber containing material that is either disposed of at landfills or incinerated at hazardous waste incinerators. Synthetic vitreous fibers are primarily used for insulation purposes and reinforcing other materials (IARC 1988; WHO 1988).

According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit substance release and offsite transfer information to the EPA. TRI, which contains this information for 1999, became available in 2001. This database is updated yearly and provides a list of industrial facilities producing, processing, and using friable asbestos and their emissions.

Environmental Fate. Synthetic vitreous fibers are fundamentally inert and are not considered to undergo transport or degradative processes in the environment analogous to organic pollutants (WHO 1988). Additional studies on the behavior of fibers in water (processes such as change in metal ion and hydroxyl ion composition, adsorption to organic materials, flocculation and precipitation, etc.) would be helpful in evaluating water-based transport of fibers, as well as in improving methods for removal of fibers from water. Transport of fibers in air is governed by processes and forces that apply to all particulate matter, and these processes are reasonably well understood (WHO 1988).

Bioavailability from Environmental Media. Synthetic vitreous fibers are generally insoluble and are not absorbed following dermal exposure. Most exposures occur to fibers in air, so the effect of matrices such as soil or food are largely unknown. It is possible that adsorption of fibers onto other dust particles could influence the location of deposition in the lung, and might even influence the cellular response to the fibers. Research to determine if this occurs and whether this is of biological significance would be helpful.

Food Chain Bioaccumulation. No data were located on synthetic vitreous fiber levels in the tissues of edible organisms. However, it is not expected that either aquatic or terrestrial organisms will accumulate a significant number of fibers in their flesh. Consequently, food chain bioaccumulation or biomagnification does not appear to be of concern. No data needs have been identified at this time.

Exposure Levels in Environmental Media. Data exist regarding the levels of synthetic vitreous fibers in ambient air (Balzer et al. 1971; NIOSH 1976; Switala et al. 1994) and indoor air (Gantner 1986; Jacob et al. 1992, 1993; Schneider et al. 1990; Trethowan et al. 1995). Generally, these levels are very low, with the exception of indoor air concentrations when insulating material is being installed (Jacob et al. 1993). No data exist regarding the levels of synthetic vitreous fibers in other environmental media such as water or soil. It would be useful to have airborne measurements of synthetic vitreous fibers near municipal landfills where construction material containing synthetic vitreous fibers are often discarded. Airborne levels in the vicinity of waste incinerators where synthetic vitreous fiber containing material may be burned would also be useful.

Exposure Levels in Humans. The general population is exposed to low levels of synthetic vitreous fibers from ambient and indoor air (Balzer et al. 1971; Gantner 1986; Jacob et al. 1992, 1993; NIOSH 1976; Switala et al. 1994). Occupational exposure is several orders of magnitude greater than exposure to the general population (Esmen and Erdal 1990). There are few data regarding the levels of synthetic vitreous fibers in human tissue due to the difficulty in analyzing for these substances (Dumortier et al. 2001; McDonald et al. 1990; Roggli 1989; Schneider and Stockholm 1981). Body burden data, particularly for workers frequently exposed to synthetic vitreous fibers occupationally, would be useful to better evaluate human exposure.

Exposures of Children. No data exist regarding the levels of synthetic vitreous fibers in children. It was shown that exposure of children residing in Europe to synthetic vitreous fibers is significantly lower than exposure to organic and other inorganic fibers (Schneider et al. 1996). Other studies have indicated that there is no correlation between respiratory problems in children and synthetic vitreous fibers concentrations in schools (Rindel et al. 1987; Schneider 1986). Children may be exposed to these substances in the same ways that adults are exposed outside the workplace, from synthetic vitreous fibers in the air. Just as children are exposed to synthetic vitreous fibers in the same way as non-occupationally exposed adults, there are no childhood-specific means to decrease exposure. Because childhood exposure to synthetic vitreous fibers is considered low and it is difficult to analyze for synthetic vitreous fibers in humans, there is no data need to conduct body burden studies at this time.

Child health data needs relating to susceptibility are discussed in 3.12.2 Identification of Data Needs: Children's Susceptibility.

Exposure Registries. No exposure registries for synthetic vitreous fibers were located. These substances are not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. These substances will be considered in the future when chemical selection is made for subregistries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to exposure to synthetic vitreous fibers.

6.8.2 Ongoing Studies

The Federal Research in Progress (FEDRIP 2002) database provides additional information obtainable from a few ongoing studies that may fill in some of the data needs identified in Section 6.8.1.

A light-scattering-based optical sensor is being developed for the online analysis of fiber diameters during the manufacturing and production process of fiberglass, by Mission Research Corporation, Santa Barbara, California. Such a sensor will allow for the rapid measurement of fiber diameters and allow for improved production efficiency and control (FEDRIP 2002). The Vortec Corporation (J.G. Hnat, principal investigator) is developing an advanced coal-fired incinerator/glass melter as a means of eliminating the solid/hazardous waste disposal problems associated with the production of insulation products and enabling glass manufacturers to use an abundant and inexpensive fuel.